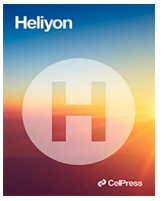
Heliyon 10 (2024) e28505

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon



Research article

The application of Moore's online learning interactions model in learning outcomes: The SOR (stimulus-organism-response) paradigm perspective

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ARTICLE INFO

Keywords:
Online learning
Interaction
Perceived usefulness
Perceived ease of use
Learning outcomes

ABSTRACT

This study presents an in-depth exploration of the impact of online learning interactions on student learning outcomes. Drawing from the Stimulus-Organism-Response (SOR) paradigm, our study focuses on the effects of online learning interactions on learners' perception usefulness and ease of use, subsequently impacting their learning outcomes. The study employs a quantitative research methodology, gathering data from a sample of 397 students enrolled in various higher education institutions across China. Data collection involved administering structured questionnaires that were designed to quantitatively assess the three components of the SOR model: stimulus (online learning interactions), organism (students' perceptions), and response (learning outcomes). The measurement model assessment and structural model assessment were conducted. Our findings reveal that online learning interactions can effectively enhance learners' perception of online learning (usefulness and ease of use), thereby influencing their learning outcomes. Notably, perceived usefulness negatively mediates the relationship between online learning interactions and learning outcomes, while perceived ease of use positively mediates this relationship. These findings offer both theoretical and practical implications.

1. Introduction

Online learning platforms such as Chaoxing, Coursera, LinkedIn Learning, and FutureLearn provide students with flexible and independent choices. China Internet Network Information Center (CNNIC) released the 46th "China Internet Development Statistics Report" shows that as of June 2020, the number of online education users in China reached 381 million [1], and by 2027, the global market value of mobile learning will reach approximately $80.1 billion [2]. In this context, China, as the world's second-largest economy, is anticipated to develop a market worth $18.8 billion by 2027 [2].

Notably, online learning is being used more meaningfully and purposefully for learning [3–5]. Consequently, online learning has become an important source for knowledge sharing and learning, enabling learners to enhance their learning processes and outcomes [6]. In fact, a study conducted by Ref. [7] emphasizes the importance of online learning for student learning.

Previous studies have confirmed the benefits of online learning [4,5]. However, in the virtual environment of online learning, the inability to achieve the desired effect in knowledge dissemination through online learning platforms has become a thorny problem [8,

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https://doi.org/10.1016/j.heliyon.2024.e28505
Received 5 September 2023; Received in revised form 11 March 2024; Accepted 20 March 2024
Available online 24 March 2024

9]. A significant difference between online learning and traditional classrooms is the mode of interaction [10] When students are able to interact effectively with instructors and classmates, they perceive the entire learning process as easy and useful [11,12]. Traditional courses provide face-to-face interaction between learner and instructors, allowing for instant feedback and personal involvement [13]. However, online learning often relies on virtual communication tools such as forums, video conferences, or emails for interaction, which may lack the same level of immediacy and personal connection [14].

Therefore, the other problem of online learning faces is the potential risks of high dropout rates and poor learning outcomes [15], leading to limited student development and wastage of educational resources. In recent years, there has been increasing research on online interaction in various fields such as online games and virtual reality [16]. In addition, online learning interactions may be a key factor influencing the learning outcomes. However, there is a lack of understanding and research on online learning interactions in the context of the online environment, which requires further attention. Clearly, the greatest challenge for learning outcomes is online learning interactions.

Researchers conducted exploratory research on learning outcomes in the context of online learning, examining antecedents such as motivation, and satisfaction [5,17]. These studies served as the initial step in investigating learning outcomes with a focus on antecedents. While existing research extensively explores various factors influencing learning outcomes in online education [7,18], there is a notable gap in understanding the specific role and dynamics of individual learning styles within the framework of Moore's Online Learning Interactions Model and the SOR Paradigm. Most studies tend to generalize learning outcomes without sufficiently accounting for the diversity in learners' cognitive (perceived usefulness and perceived ease of use) and behavioral approaches (online learning interaction). This study aims to investigate the antecedents that impact learning outcomes, namely online learning interactions, perceived usefulness, and perceived ease of use, by applying the Stimulus-Organism-Response (SOR) model [19] to the context of knowledge-based online learning.

In this study, online learning interactions serves as the stimulus factor. Online learning interactions encompasses learner-learner, learner-instructor, and learner-content interactions [20]. We conceptualize online learning interactions as the process of engaging and interacting with educational content, instructors, and other learners in a virtual or online learning environment. It involves the exchange of information, ideas, and feedback through various digital tools and communication channels.

In this study, the organism's (i.e., perceived usefulness and perceived ease of use) response is the learning outcomes. Online learning interactions contributes to assisting students in cognitive processes and understanding of the learning content (usefulness and ease of use), thereby encouraging students to achieve the expected learning outcomes [21]. The cognitive processes regarding the learning process and content significantly influence learning outcomes, as they can impede the overall learning process. Although interaction may enhance learners' perception of usefulness and ease of use in traditional class mode, the nature of this relationship remains unknown in the context of online learning.

This study aims to address the following research question: "How does online learning interactions induce perceived usefulness and perceived ease of use, ultimately influencing learning outcomes?" We utilize the Stimulus-Organism-Response paradigm to determine whether online learning interactions impacts learner's perception of the learning process and content (usefulness and ease of use) and influences learning outcomes subsequently.

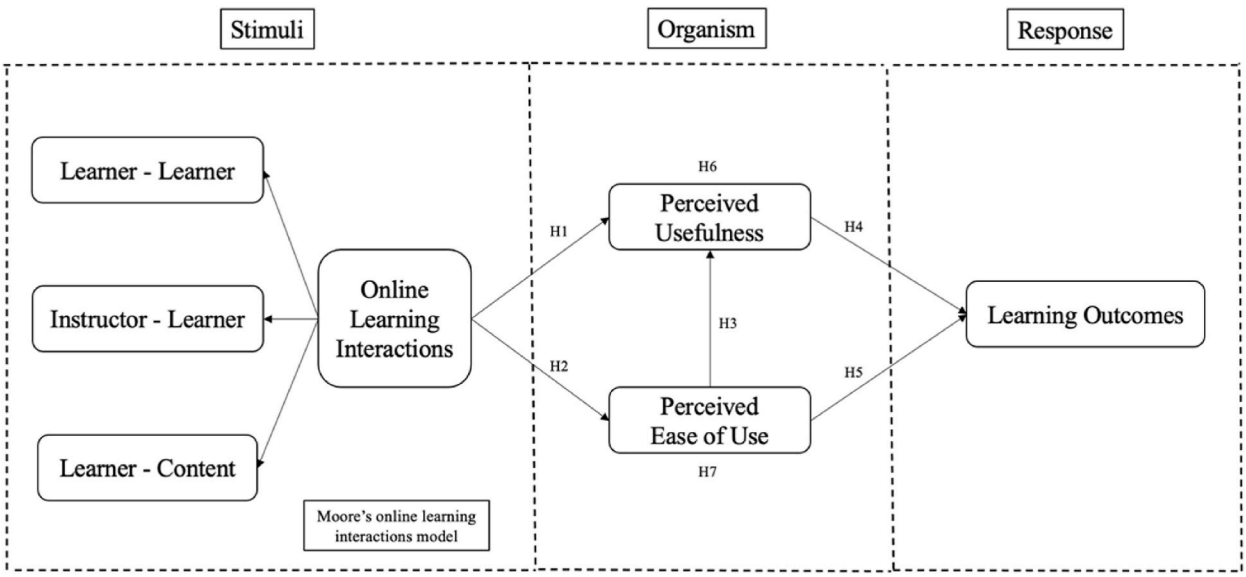

Fig. 1. The proposed theoretical framework and hypothesized relationship.

2. Theoretical framework

The Stimulus-Organism-Response (SOR) model, employed in the field of environmental psychology and has been adopted in various disciplines, including education. It explains how different environmental factors act as stimuli (S) that impact an individual's internal state (O), leading to behavioural responses (R) [19]. This model illustrates how external stimuli in the environment reinforce an individual's internal state [22]. As stated by Mehrabian and Russell (1974) [19], individuals make choices based on their internal state and subsequently respond accordingly. In educational contexts, the SOR model provides a structured framework for understanding how different environmental stimuli affect learners' internal cognitive and affective states, consequently influencing their behavioural responses [23].

In traditional educational settings, the 'Stimulus' component can include various elements such as the physical classroom environment, teaching methods, educational materials, and social interactions [24]. These stimuli evoke specific cognitive and affective states in students (the 'Organism'), such as motivation, engagement, frustration, or satisfaction. These internal states then influence the students' 'Response' in terms of academic performance, participation in class activities, and overall learning outcomes. While in online learning environments, the SOR model adapts to the digital context [22,25]. Given its extensive use in studying online user behaviour, the SOR model holds great relevance to our research context. As shown in Fig. 1.

2.1. Online learning interactions as stimulus

Stimulus refers to the context that users encounter [19]. The significance of technology in education cannot be underestimated, particularly online platforms that offer learners a broader array of learning resources and more independent, flexible learning approaches, thereby enhancing learning outcomes and catering to individualized learner needs [7].

Existing literature also underscores concerns regarding online learning interactions, which align with technological advancements [26]. For instance, smooth communication and network can bring high quality real-time interactive experiences. Consequently, the online interactive learning environment is regarded as a "stimulus" influencing the activation of psychological characteristics and eliciting corresponding behavioural responses from learners. Consistent with Moore (1989)'s [20] online learning interactive model, our proposed model measures online learning interactions across three different dimensions: learner-learner, learner-instructor, and learner-content.

2.1.1. Instructor – learner interactions

In terms of the role of learner-instructor, the effectiveness of online learning depends heavily on the quality of interaction between students and teachers [27]. To foster engagement in online learning, educators can employ various strategies. The online discussion promotes student-led dialogues in video chats, while chat features enable comprehension checks [28]. The flipped classroom model encourages deeper discussions through asynchronous and synchronous sessions [29]. Online forums facilitate continuous dialogue and peer feedback [30]. These approaches not only improve interaction in online classrooms but also cater to diverse student profiles and learning preferences.

2.1.2. Learner – learner interactions

Learner-learner interaction is a two-way communication between learners [20]. In other words, it can be happened between one learner and another, or between several learners [31]. In the realm of online education, the dynamics of learner-learner interaction play a pivotal role in constructing a rich, collaborative learning environment [32]. Central to this interactive paradigm is the concept of peer support and knowledge sharing. The online discussions and debates among peers stimulate a rigorous examination of course material, encouraging learners to articulate and defend their viewpoints, thus deepening their cognitive engagement with the subject matter [33]. Such interactions are instrumental in not only disseminating knowledge but also in cultivating critical thinking and analytical skills.

2.1.3. Learner – content interactions

Learner-content interaction is the interaction between the student and the subject, which is a highly personalized process, with help from the instructor [20]. This interaction is not merely about absorbing information but involves an active, critical engagement with the educational material, which is vital for a profound and lasting understanding of the subject matter [34]. The essence of learner-content interaction lies in the nature and design of the educational material itself. Content in online learning environments needs to be more than just informative, it must be engaging, interactive, and thought-provoking [35]. The incorporation of multimedia elements, such as videos, podcasts, and interactive simulations, plays a critical role in this regard. These elements make the learning experience more dynamic and cater to different learning styles, thereby enhancing learner engagement and comprehension.

In this study, online learning interactions is defined as the bidirectional communication and interaction between learner, instructor, and content when engaging in educational and learning activities on the internet or online platforms. Using online learning platforms for education poses a potential risk of limited real-time interaction. However, interaction is an important method for promoting learner's thinking and understanding, enhancing learning motivation and engagement. Interactive environments provide opportunities for communication, participation in discussions, and collaborative problem-solving with others, which contribute to deepening understanding, improving memory, and achieving better academic performance [26].

2.2. Perceived usefulness and perceived ease of use as organism

The SOR (Stimulus-Organism-Response) paradigm reveals the intervening role of environmental stimuli on the organism of users [19]. Our study includes perceived usefulness and perceived ease of use of online learning learner as an organism in the research model. Perceived usefulness is a term to describe an individual's subjective belief or perception of the extent to which a particular technology, system, or tool can enhance their performance, improve productivity, or provide benefits in achieving specific goals or tasks [36]. Perceived ease of use is an individual's subjective perception of the level of effort required to use a particular technology, system, or tool [37]. These two concepts were commonly used in the field of technology acceptance and user behaviour research [38], while the literature in the online learning environment is relatively limited.

Expanding into the online learning environment is highly desirable because with the development of digital technology, interactivity becomes easier to achieve in online learning platforms, such as the development of instant messaging tools, video conferencing, and virtual classrooms [39] This study employs the terms perceived usefulness and perceived ease of use to support the proposition that online learning interaction enhances users' perception of the learning process (perceived usefulness, perceived ease of use). When applying the SOR paradigm, perceived usefulness and perceived ease of use act as an organism generated by online learning interactions, which impact the learning outcomes.

2.3. Learning outcomes as response

The SOR paradigm reveals that the influence of external stimuli on behavior is mediated by the user's internal organism [19]. In the context of online learning, users are frequently exposed to diverse technological aspects and attributes of online learning platforms, such as interaction [40], which can potentially influence students' learning outcomes. Hence, within the current theoretical framework, we consider the user's learning outcomes as response. Online learning platforms facilitate knowledge acquisition by offering interactive features that support collaborative learning among students [41] Moreover, through interactive learning experiences, students perceive the assimilation of valuable learning content as more accessible. These learning processes collectively impact the learners' ultimate learning outcomes. Building upon these discoveries, our theoretical model employs the learners' learning outcomes as the dependent variable. The subsequent sections present the hypotheses formulated in this study.

3. Hypothesis development

3.1. Online learning interactions and perceived usefulness, perceived ease of use

The understanding of online learning interactions has been studied in different context [42,43]. Moore (1989) [20] considered that online learning interactions refer to the engagement and communication that takes place between learners, instructors, and resources in an online learning environment.

In this study, we regard the issue of online learning interactions from three perspectives: learner-learner interaction, learner-instructor interaction, and learner-content interaction. These three types of interaction are crucial in an online learning environment. For example, students collaborate with each other through online discussion forums, online sharing, and collaborative editing of documents. Teachers can engage in real-time discussions with students using video conferencing tools. Additionally, online learning platforms often provide interactive learning resources such as interactive simulations, virtual experiments, multimedia content, etc.

These three aspects account for the majority of interactions that arise when students study on online learning platforms. Online learning interactions that promote active engagement, personalization, collaboration, access to resources, and immediate feedback contribute to the perceived usefulness of the learning experience [44]. When learners feel that the online learning environment aligns with their needs, supports their goals, and facilitates meaningful interactions, they are more likely to perceive it as valuable and beneficial [11]. Besides, a well-designed online learning platforms often incorporate intuitive and user-friendly interfaces [45]. Clear navigation, organized course materials, and interactive elements contribute to a positive user experience [46]. When learners find it easy to navigate through the platform and locate the information they need, they perceive the system as easy to use. Therefore, we propose the following hypothesis.

H1. Online learning interactions has a significant impact on perceived usefulness.

H2. Online learning interactions has a significant impact on perceived ease of use.

3.2. Perceived ease of use and perceived usefulness

Perceived usefulness and perceived ease of use are important factors determining user acceptance and adoption of technology, commonly used to understand user behaviour in online learning environments [11]. Perceived ease of use pertains to the degree to which an individual perceives the use of a specific system as effortless [37]. In the online learning environment, it can be related to the simplicity of navigating platforms, understanding course materials, and communicating and learning with technological tools [11]. On the other hand, perceived usefulness is the extent to which a person believes that using a specific technology will enhance their performance and make their tasks easier to accomplish [36]. Online learning platforms have the potential to significantly enhance collaborative activities by offering tools that foster student engagement and promote the sharing of knowledge [12].

Perceived ease of use is positively related to perceived usefulness in the contexts of information technology and information

systems [47]. In addition, Shin and Perdue, (2019) [48] also mentioned that there is a significant influence between perceived ease of use and perceived usefulness, and perceived ease of use has a positive influence on perceived usefulness. Similarly, Shin and Perdue, (2019) [48] also believes that perceived ease of use has a significant effect on perceived usefulness, and perceived ease of use has a positive effect on perceived usefulness. Daud et al. (2018) [49] also proposed that perceived ease of use is a prerequisite for perceived usefulness.

The above-mentioned research emphasizes that the perceived usefulness of online collaborative learning largely depends on the perceived ease of use. Based on these studies, we propose the following hypothesis.

H3. Perceived ease of use has a significant impact on perceived usefulness.

3.3. Perceived usefulness, perceived ease of use and learning outcomes

Learning outcomes refer to specific knowledge, skills, abilities, or attitudes that students should be able to demonstrate, understand, or experience in learning activities such as courses or projects [7]. They form the basis of educational programs [8]. Tsai et al. (2021) [18] found that in intelligent learning environments, perceived usefulness and ease of use are important factors in predicting satisfaction and learning outcomes. Furthermore, perceived ease of use and usefulness as an intervention have enhanced learners' perception of self-regulation and cognitive absorption of online learning platforms [50].

In a learning environment, if a tool or technology is perceived as useful, learners are more likely to engage with it and make full use of it [44]. This engagement can lead to better understanding, retention, and application of acquired knowledge, thereby improving learning outcomes. Additionally, if a learning tool or technology is easy to use, learners can focus more on the learning content rather than struggling with the technology itself [51]. In other words, the usability of online learning platforms, interfaces, and materials reduces cognitive load. When learners can easily navigate online resources without being burdened by intricate user interfaces or technical difficulties, they can focus their energy on comprehending the content. Reducing cognitive load can enhance comprehension and the ability to effectively process information, resulting in better learning outcomes. Thus, we propose the following hypothesis.

H4. Perceived usefulness has a significant impact on learning outcomes.

H5. Perceived ease of use has a significant impact on learning outcomes.

3.4. Perceived usefulness, perceived ease of use as mediator

Perceived usefulness can motivate learners to become more self-directed in their learning process. Online learning often requires a high degree of self-motivation and independence and perceiving the learning platform as useful can encourage this behavior. As Heethal Jaiprakash. (2022) [29] discovered, if students perceive the online learning tools as useful, they are more likely to continue using them consistently, which allows for more regular interactions with the learning materials. The study conducted by Karthick and Sindhu (2022) [52] revealed that the continual interaction can improve knowledge retention and application, leading to better learning outcomes.

In addition, the perceived ease of use of an online learning platform can greatly affect students' interaction with the platform and their learning outcomes. The easier the platform is to use; the more likely students are to use it effectively and succeed in their learning objectives. Tzafilkou and Protogeros (2020) [12] confirmed that if students find an online learning system easy to use, they're more likely to use it frequently and consistently. Regular interaction with learning materials can improve knowledge retention and, consequently, learning outcomes. Thus, we propose the following hypothesis.

H6. Perceived usefulness mediating the association of online learning interactions and learning outcomes.

H7. Perceived ease of use mediating the association of online learning interactions and learning outcomes.

4. Methods

4.1. Participants and procedure

This study was approved by Jawatankuasa Etika Penyelidikan Manusia Universiti Sains Malaysia (JEPeM-USM) and assigned study protocol code USM/JEPeM/22110735, and this study confirm that informed consent was obtained from all participants. In order to examine the validity of our suggested model (Fig. 1), we gathered information from a group of Chinese university students using a survey. These students were particularly suitable for our research as they possessed greater familiarity with online learning platforms due to their academic pursuits.

Hair et al. (2021) [53] suggested using G*Power software to estimate the required sample size for conducting structural equation modelling. This model comprises three predictor factors, and in order to achieve a medium effect size and a power of 0.8, a minimum sample size of 77 is necessary. However, to mitigate bias in online surveys, Kirchherr and Charles (2018) [54] recommend increasing the sample size. Ultimately, we gathered a total of 459 questionnaires, excluding 62 invalid ones, resulting in 397 valid responses. These responses were collected between March and June 2023. Among the participants, 40.9% identified as male, while 59.1% identified as female. The largest portion of participants fell within the 18 to 19 age range, comprising 29.51% of the sample. The next significant group was the 22 to 23 accounted for 25.59% of the respondents, 20 to 21 age categories, making up 22.9% of the

participants, the remained participants were aged from 24 to 25 accounted for 22%.

4.2. Measurements

The constructs were formulated based on existing literature and adapted to the specific context of learning outcomes. To evaluate each item, a Likert five-point scale was utilized, ranging from (1) strongly disagree to (5) strongly agree.

Online learning interactions: the measurement of learning interactions was adapted from Kuo (2014) [55] with 11 items. Sample item is "I asked the instructor in different ways through email, discussion boards, instant messaging tools, etc."

Learning outcomes: the measurement of learning outcomes was adapted from Eom and Ashill (2006) [56] with 3 items. One sample item is "The quality of the learning experience in online courses is good".

Perceived usefulness: the perceived usefulness was measured with 6 items adapted from Davis (1989) [36]. One sample is "Using online education platform would improve my learning performance."

Perceived ease of use: the perceived ease of use was measured with 4 items adapted from Davis (1989) [36]. Sample item is "Using online education platform would make it easier for my study."

5. Results

5.1. Normality test

In this research, SmartPLS was utilized for structural equation modeling (SEM), a subset of regression analysis known for dealing with data is non-normal distributed [57]. This method necessitates the fulfilment of Ordinary Least Squares (OLS) assumptions. Hence, conducting a normality test is crucial to assess the data's normality concerning the study's variables. For this purpose, two normality tests, specifically, the Shapiro-Wilk Method and the Kolmogorov-Smirnov test were conducted by SPSS. According to the following results of the Shapiro-Wilk and Kolmogorov-Smirnov test in Table 1, all the variables' p-value of this study achieved 0.000, which suggested the data is non-normal distribution.

5.2. Common method bias

The study utilized the PLS-algorithm and employed the marker variable technique to investigate potential bias in commonly used methods (see Fig. 2). The rationale behind this approach is that it assesses the impact of method variance on statistical analysis [58]. The findings of the research indicate that incorporating marker variables in the research model resulted in a slight change in the R^2 value, specifically from 0.001 to 0.014, representing less than a 10% difference. These results provide evidence that the dataset is not affected by common method bias issue [59]. The marker variable results are presented in Table 2.

5.3. The measurement model

The internal consistency reliability of the measurements was evaluated using Cronbach's alpha and composite reliability. The results obtained demonstrate satisfactory internal consistency within the model, as both the Cronbach's alpha values and composite reliability scores surpass the threshold of 0.7 [53]. Furthermore, the indicator reliability is deemed satisfactory, as indicated by outer loadings exceeding 0.6 [60]. Additionally, the study confirmed convergent validity, with an average variance extracted that surpasses 0.5 [53]. The results are shown in Table 3.

To assess the discriminant validity, we employed the heterotrait-monotrait (HTMT) ratio technique [61]. The results indicate that none of the constructs violated the HTMT threshold of 0.85, thereby confirming the presence of discriminant validity [61]. The results meeting the threshold are presented in Table 4.

5.4. The structural model

After the reliability and validity of the measurement model were verified, path relationships were investigated using 5000 bootstrap samples [53]. The results of the structural model can be observed in Tables 4 and 5.

Table 1
The value of normality test.

	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	*df*	*p*	Statistic	*df*	*p*
OLI	0.116	397	0.000	0.956	397	0.000
PU	0.121	397	0.000	0.962	397	0.000
PEOU	0.146	397	0.000	0.962	397	0.000
LO	0.122	397	0.000	0.959	397	0.000

Notes: IL - > Instructor-Learner, LC - > Learning-Content, LL - > Learner-Learner, LO - > Learning Outcomes, PEOU - > Perceived Ease of Use, PU - > Perceived Usefulness.

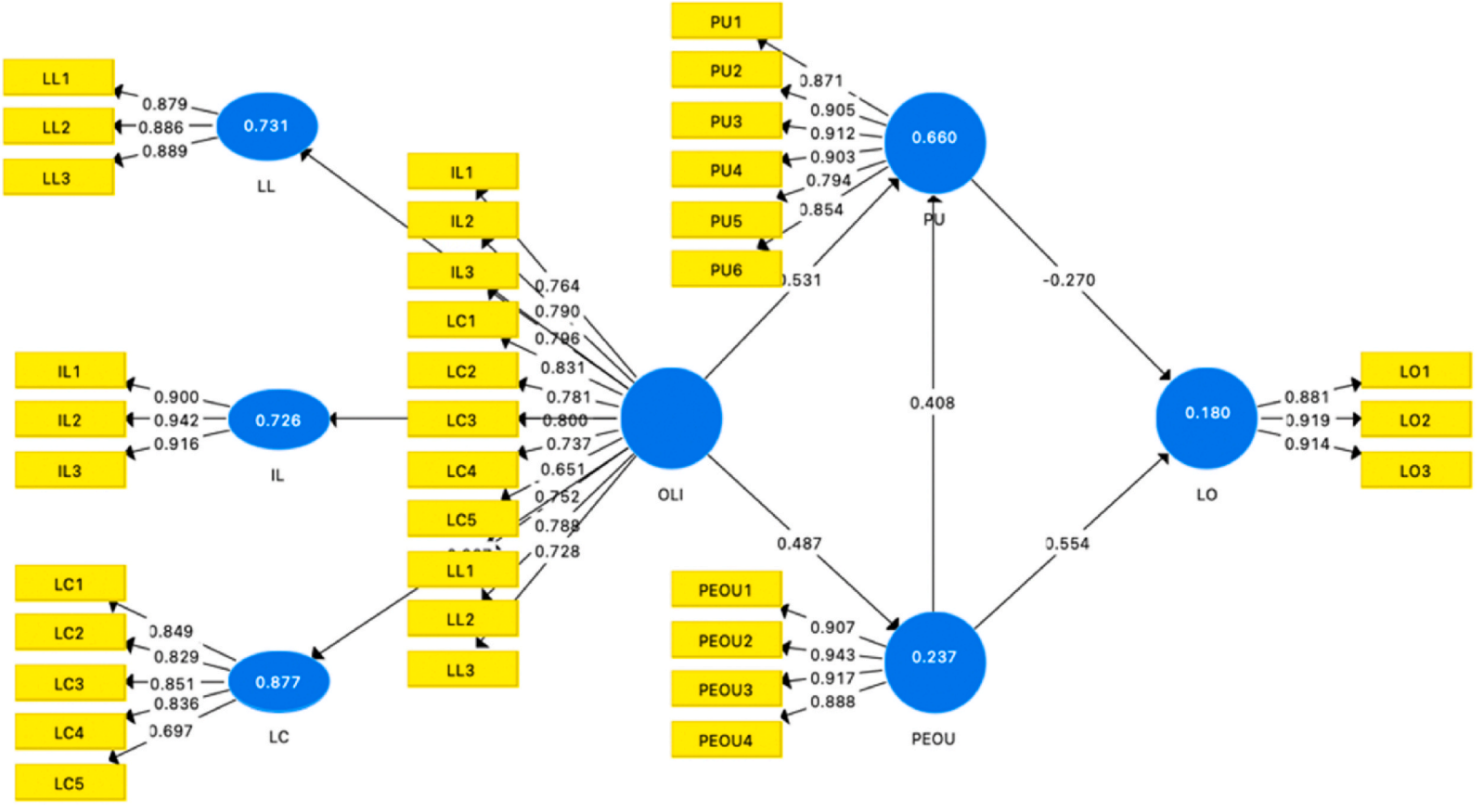

Fig. 2. The results of PLS-algorithm.

Table 2
R^2 value Comparison.

Relationships	Without marker variable	With marker variable
IL	0.726	0.726
LC	0.877	0.877
LL	0.731	0.731
LO	0.180	0.184
PEOU	0.237	0.238
PU	0.660	0.674

Notes: IL - > Instructor-Learner, LC - > Learning-Content, LL - > Learner-Learner, LO - > Learning Outcomes, PEOU - > Perceived Ease of Use, PU - > Perceived Usefulness.

Table 3
The reliability and validity results.

Constructs	Factor Loadings	Cronbach's Alpha	CR	AVE
Learner-Learner				
LL1	0.879	0.861	0.915	0.783
LL2	0.886			
LL3	0.889			
Instructor-Learner				
IL1	0.90	0.908	0.943	0.846
IL2	0.942			
IL3	0.916			
Learner-Content				
LC1	0.849	0.872	0.907	0.663
LC2	0.829			
LC3	0.851			
LC4	0.836			
LC5	0.700			
Perceived Usefulness				
PU1	0.871	0.938	0.951	0.764
PU2	0.905			
PU3	0.912			
PU4	0.903			
PU5	0.794			
PU6	0.854			
Perceived Ease of Use				
PEOU1	0.907	0.934	0.953	0.836
PEOU2	0.943			
PEOU3	0.917			
PEOU4	0.888			
Learning Outcomes				
LO1	0.881	0.889	0.931	0.819
LO2	0.919			
LO3	0.914			

Notes: IL - > Instructor-Learner, LC - > Learning-Content, LL - > Learner-Learner, LO - > Learning Outcomes, PEOU - > Perceived Ease of Use, PU - > Perceived Usefulness.

Table 4
Discriminant validity: Fornell-Larcker Criterion.

	IL	LC	LL	LO	OLI	PEOU	PU
IL							
LC	0.781						
LL	0.668	0.827					
LO	0.031	0.068	0.039				
PEOU	0.373	0.554	0.471	0.41	0.523		
PU	0.637	0.777	0.701	0.111	0.782	0.708	

Notes: IL - > Instructor-Learner, LC - > Learning-Content, LL - > Learner-Learner, LO - > Learning Outcomes, PEOU - > Perceived Ease of Use, PU - > Perceived Usefulness.

5.4.1. Hypothesis testing

This study conducted 5000 bootstrap procedures to examine the hypothesis. As shown in Table 5, the results of direct effect hypotheses are presented. Online learning interactions was significantly influence on perceived usefulness ($\beta = 0.531$, t-value $= 10.289$, $p < 0.01$) and perceived ease of use ($\beta = 0.487$, t-value $= 8.471$, $p < 0.01$), therefore, the hypothesis 1,2 was supported. Besides,

Table 5
Direct effect hypotheses.

Hypothesis					Bootstrapped CI BC		
Variable Relationship	Path Coefficient Beta (β)	Standard Deviation (STDEV)	T Statistics (|O/STDEV|)	*P* Values	2.5% LL	97.5% UL	Decision
OLI - > PU	0.531	0.052	10.289	0	0.429	0.624	Supported
OLI - > PEOU	0.487	0.058	8.471	0	0.372	0.592	Supported
PEOU - > PU	0.408	0.050	8.112	0	0.308	0.502	Supported
PU - > LO	−0.270	0.066	4.101	0	−0.396	−0.139	Supported
PEOU - > LO	0.554	0.058	9.515	0	0.447	0.669	Supported

Notes: Significant at p < 0.01**, OLI - > Online Learning Interactions, LO - > Learning Outcomes, PEOU - > Perceived Ease of Use, PU - > Perceived Usefulness.

perceived ease of use was found positively related to perceived usefulness (β = 0.408, *t*-value = 8.112, $p < 0.01$) which supported hypothesis 3. In addition, perceived usefulness (β = −0.270, *t*-value = 4.101, $p < 0.01$) and perceived ease of use (β = 0.554, *t*-value = 9.515, $p < 0.01$) was both significantly influence on learning outcomes, thus, hypothesis 4, 5 was supported.

Hair et al. (2021) [53] suggested to run bootstrapping to examine the mediation effect. Table 6 showed that the perceived usefulness mediates the relationship between online learning interactions and learning outcomes (β = −0.143, *t*-value = 3.652, $p < 0.01$), perceived ease of use mediates the relationship between online learning interactions and learning outcomes (β = 0.270, *t*-value = 6.102, $p < 0.01$), thus, hypothesis 6, 7 was supported.

5.4.2. Coefficient of determination (R^2) and predictive relevance (Q^2)

Additionally, to evaluate the overall effectiveness of the model, Hair et al. (2021) suggested utilizing the coefficient of determination (R^2) and predictive correlation (Q^2). Our results demonstrate that the combined influence of perceived usefulness and perceived ease of use explains 18% of the variability in learning outcomes. Furthermore, the positive Q^2 value (specifically, Q^2 learning outcomes = 0.144) in the predictive correlation between the exogenous and endogenous variables is presented in Table 7.

6. Discussion

According to the SOR paradigm, online learning interactions was regarded as environment stimulus which influence learner's perceived usefulness and ease of use of online learning as an organism, and later impact on learner's learning outcomes as response. Out results indicate the hypotheses regarding the relationship between online learning interactions and perceived usefulness, perceived ease of use suggest that online learning interactions promotes learner's perception of online learning platform (i.e., usefulness, ease of use).

A possible explanation for this finding is that high-quality interactions can enhance the learning experience, making it more engaging and efficient. For example, discussions can promote deeper understanding, peer feedback can improve skills, and interaction with the platform itself (such as navigation or tools) can make learning easier. When learners have positive experiences with these interactions, they are more likely to perceive the platform as useful. This finding aligns with the results of [41], which suggest that practical platforms should focus on facilitating high-quality, meaningful interactions. Additionally, as learners engage more with the platform, they become more familiar with its features and functions, reducing the perceived complexity of using the platform and increasing perceived ease of use. This finding also supports previous research conclusions that interaction with the platform helps learners develop a sense of technological self-efficacy. As learners successfully navigate the platform and complete tasks, their confidence grows, making the platform appear easier to use [55]. Besides, the hypothesis testing also presents the significant relationship between perceived ease of use and perceived usefulness. The possible illustration might be that the ease of use of the learning platform removes barriers for learners, who are likely to use it more frequently. The more learners use the platform, the more opportunity they have to recognize its benefits and thus enhance its perceived usefulness.

Furthermore, our findings indicate that both perceived usefulness and ease of use have a substantial influence on learning outcomes. However, perceived usefulness demonstrates a negative association with learning outcomes, while perceived ease of use presents positive results. The similar results show in the mediating effect as well. Therefore, our results are partially different from previous studies which support perceived usefulness promotes satisfactory learning outcomes [18,62]. This implies that learners who

Table 6
Indirect effect hypotheses.

Hypothesis					Bootstrapped CI BC		
Variable Relationship	Path Coefficient Beta (β)	Standard Deviation (STDEV)	T Statistics (|O/STDEV|)	*P* Values	2.5% LL	97.5% UL	Decision
OLI - > PU - > LO	−0.143	0.039	3.652	0	−0.222	−0.069	Supported
OLI - > PEOU- > LO	0.270	0.044	6.102	0	0.189	0.364	Supported

Notes: Significant at p < 0.01**, OLI - > Online Learning Interactions, LO - > Learning Outcomes, PEOU - > Perceived Ease of Use, PU - > Perceived Usefulness.

Table 7
The R^2 and Q^2 value.

Dependent Variables	R^2	Q^2
IL	0.726	0.609
LC	0.877	0.576
LL	0.731	0.565
LO	0.180	0.144
PEOU	0.237	0.193
PU	0.660	0.496

Notes: IL - > Instructor-Learner, LC - > Learning-Content, LL - > Learner-Learner, LO - > Learning Outcomes, PEOU - > Perceived Ease of Use, PU - > Perceived Usefulness.

perceive the online learning tools as more useful might be seeing worse learning outcomes. This does seem counterintuitive since we would usually expect useful tools to support learning. However, here are a few reasons why this negative correlation might exist.

Firstly, students may rely excessively on online learning platforms, believing that technology can do most of the learning for them, while neglecting other important aspects of learning such as critical thinking, self-study, or collaborative learning. This could result in reduced efforts in understanding and digesting learning materials, thus negatively impacting their learning outcomes. Secondly, some online learning tools have many features that, although considered useful, may distract their attention from the core learning process. For example, hyperlinks, chat functions, or multimedia may divert students' attention away from the main content. Moreover, the perceived usefulness may lead to the adoption of too many online tools or features simultaneously, which can result in cognitive overload. Students may struggle to manage different platforms and technologies, consuming valuable time and energy instead of engaging in genuine learning. Lastly, if the perceived usefulness of online platform content leads students to prefer passive online self-study over participating in interactive courses (such as joining discussion groups), this may result in a decline in discussion and exchange of ideas, which are crucial for deep learning.

7. Implications

The study uniquely combines Moore's Online Learning Interactions model with the SOR paradigm. This integration is novel in the context of online education research. The detailed application of the SOR model, originally from environmental psychology, while in the context of online learning, it is a creative approach that offers a new lens for examining how environmental stimuli (online learning interactions) impact the organism (learner). Specifically, this study validates the SOR model, contributing to the examination of factors preceding and mediating the effects of learning outcomes. The interactive nature of online learning plays a vital role in how learners perceive knowledge (i.e., usefulness and ease of use). It serves as a stimulus that influences learners' internal learning states.

Furthermore, as the SOR model proposed by Ref. [19], the individual's internal state plays a crucial role in shaping the influence of environmental stimuli on user behaviour. It has been discovered that perceived usefulness and perceived ease of use act as mediators in the relationship between online learning interactions and learning outcomes. While previous research has primarily focused on interactions within online games and virtual reality, this study addresses the overlooked aspect of interaction and perception within online learning platforms. Therefore, this research suggests ways to enhance the online learning experience, such as improve the perceived ease of use of online learning system, since it potentially leading to better retention rates and more positive educational outcomes. The findings also provide actionable insights for designing more effective and engaging online courses. Significantly, this study examines, for the first time, how learners' perception of online learning (in terms of usefulness and ease of use) impacts their learning outcomes under the environmental stimulus of online learning interactions, using the SOR model as a theoretical framework.

In addition to theoretical contributions, our research also has practical implications for educators, educational institutions, and learners on how to improve learning outcomes. For educators, by observing learner interactions and understanding how learners engage with online learning materials, they can adjust the pace, format, and interactive elements of online courses to design more effective course content. For educational institutions, by studying how learners interact with their platforms, companies can design more user-friendly interfaces. For students, they need to be aware that active participation is necessary during online learning. They should choose online learning platforms that suit their learning methods but avoid becoming too absorbed in the technical aspects of the online platform, as it can be distracting from the learning process. Online learning technology should be seen as a tool for supplemental learning rather than excessive dependence on it.

8. Limitations and future studies

This study has made valuable contributions to the existing literature, but it is important to recognize its limitations. A primary limitation is the sample bias, as the research exclusively sampled Chinese university students, which may not represent the diverse experiences and perceptions of students from different educational systems and cultural backgrounds. Additionally, the cross-sectional nature of the study's design restricts its ability to track changes and developments over time, limiting the understanding of the dynamic nature of online learning experiences. Besides, the study's focus on a singular cultural context limits its applicability to global online learning environments, as cultural, social, and educational dynamics can significantly influence people's experiences [63]. A broader cultural scope is necessary to enhance the universality of the research findings. Moreover, the absence of a longitudinal approach in the study's design is a notable limitation, as it would allow for the examination of how student perceptions and learning outcomes develop

over time, providing deeper insights into the long-term efficacy of online learning interactions.

Further limitations include the reliance on self-reported data, which is subject to biases like social desirability and recall bias, potentially leading to skewed results. Psychological factors like motivation, learning styles, and prior experiences with technology, which can significantly influence how students interact with and perceive online learning platforms, are also not extensively explored.

In summary, while the research contributes significantly to the field of online education, acknowledging these limitations is crucial for an accurate interpretation of its findings and for guiding future research directions. Future studies should aim to address these limitations by incorporating diverse methodologies, broader participant samples, and a more comprehensive consideration of the myriad factors influencing online learning.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

There is no fundings for this work.

Data availability statement

Data will be made available on request.

CRediT authorship contribution statement

Junjie Pan: Writing – original draft, Validation, Resources, Investigation. **Nor Asniza Ishak:** Supervision, Resources, Project administration, Conceptualization. **Yao Qin:** Writing – review & editing, Writing – original draft, Visualization, Software, Methodology.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2024.e28505

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